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TOPEX/Poseidon Precision Orbit Determination: "Quick-Look" Operations With GPS and Laser Tracking Data

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This paper presents a summary of TOPEX/Poseidon "quick-look" orbit determination using Global Positioning System (GPS) and satellite laser ranging (SLR) tracking data. The primary feature of this endeavor is that orbits are produced with small radial position errors (<5 cm RMS), on a short production schedule (≤ 4 days), with minimal resources.

The TOPEX/Poseidon spacecraft, launched on 10 August 1992, has gathered precise sea-level measurements for over two years. To take advantage of the quality of these measurements, the radial orbit component must be known to better than a decimeter. "Quick-look" or-bits using two-way laser tracking data have been created for production of Interim Geophysical Data Records (IGDRs) since launch. This effort has been updated with new geodetic models and expanded to include GPS data. These changes resulted in more accurate orbits and added redundancy to the quick-look processing.

The orbit production with both SLR and GPS data has provided an opportunity to use updated station location, gravity field, and tide models. The impact of these updates upon orbit quality is reported. With the two data types, there are actually five data combination scenarios which can occur during operations: (i) GPS (w/ Anti-Spoofing) & SLR, (ii) GPS (w/o Anti-Spoofing) & SLR, (iii) GPS (w/Anti-Spoofing), (iv) GPS (w/o Anti-Spoofing), and (v) SLR only. Based on mission experience to date, the first scenario is most frequently encountered, and the last is the former processing mode. The filtering methodology is matched to the data combination available. Comparisons of these orbits are made to existing precision orbit ephemerides to demonstrate their relative accuracy as an orbit product.

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The TOPEX/Poseidon (T/P) spacecraft was launched into a 1334 km altitude orbit in August 1992, and is in the final months of its primary mission, with a three-year extended mission ahead of it. The mission has been jointly conducted by the United States National Aeronautics and Space Administration (NASA) and the French space agency, Centre National d'Etudes Spatiales (CNES). The T/P near-circular orbit defines a ground track with a ten-day repeat cycle; at the time this document was being prepared, 106 such cycles had been completed .

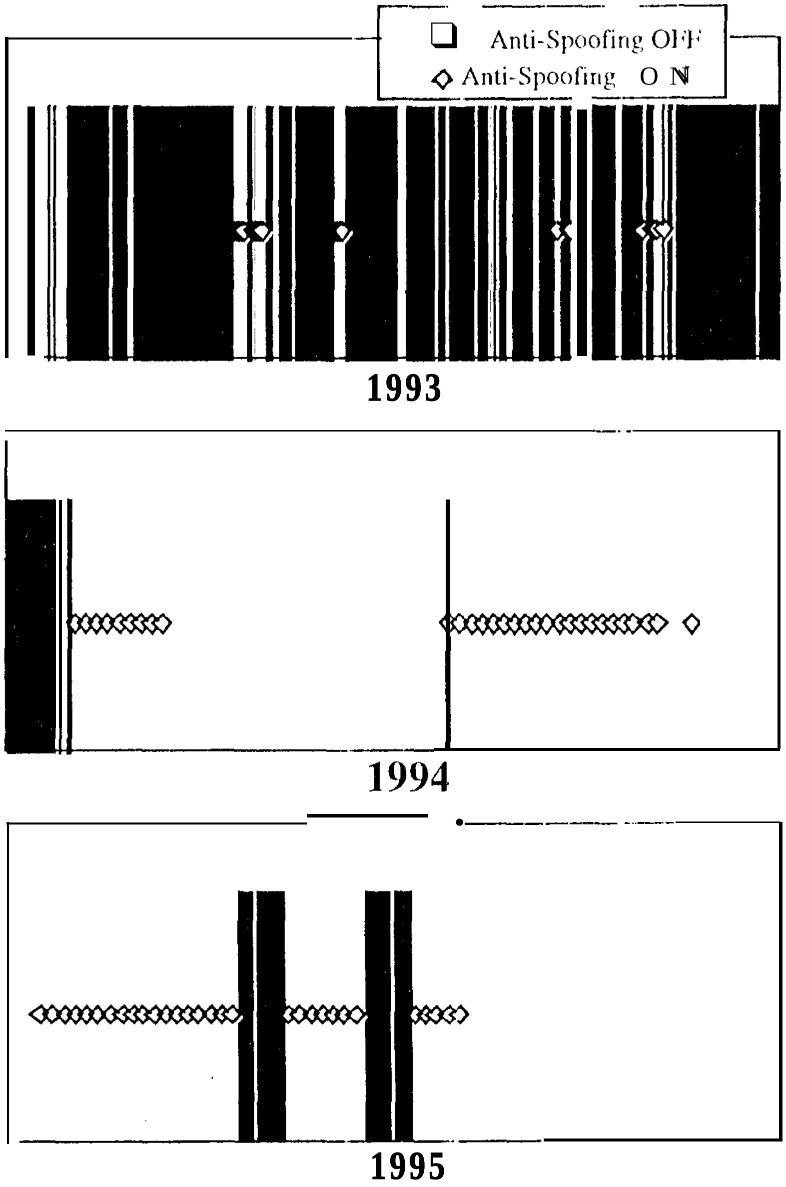
The principal goal of T/P is to measure sea level to such an accuracy that small-amplitude, basin-wide sca level changes caused by large-scale ocean circulation can be detected. To detect these changes, the T/P sensor system must bc able to measure the sea level with decimeter accuracy. '1'bus, the radial component of the orbit must be known to at least the same accuracy. To achieve this end, the T/P spacecraft is configured with three independent precision tracking systems: (i) a Laser Retroreflector Array (LRA) (NASA), (ii) a Doppler Orbitography and Radio-Positioning Integrated by Satellite (DORIS) Dual-Doppler Tracking System Receiver (CNES), and (iii) a Global Positioning System Demonstration Receiver (GPSDR) (NASA), which is experimental. The LRA is used with a network of satellite laser ranging (SLR) stations to provide the NASA baseline tracking data for precision orbit determination. The DORIS tracking system provides the CNES baseline tracking data using microwave Doppler techniques for precision orbit determination. The DORIS system is composed of an onboard receiver and a network of 40 to 50 ground transmitting stations, providing all-weather global tracking of the satellite. The signals are transmitted at two frequencies to allow removal of the effects of ionospheric free electrons in the tracking data. The GPSDR, also operating at two frequencies, uses GPS differential ranging for precise, continuous tracking of the spacecraft with better than decimeter accuracy.

Precision orbit ephemerides (hereafter referred to as POEs), are created once pcr ten-day (127-orbit) cycle, thirty days after the tracking data has been collected (after-the-track), using the non-experimental SLR and DORIS data types. These orbits, created at the Goddard Space Flight Center (GSFC), are used for the construction of the mission Geophysical Data Records (GDRs). In April 1995, the set of geodetic models (gravity field, ocean tides, station locations, etc.) used for I'OE production was updated to account for the improvement in modeling that had taken place since launch (Reference 1).

Early after launch, it became evident that precision orbits could bc generated quickly in support of Interim Geophysical Data Record (IGDR) production. S1 .R data could be used to construct (i) daily fits within 3-5 days after-the-track and (ii) verification orbits to support POE production. These orbits are called "Medium Precision Orbit Ephemerides," or MOEs. A small team, referred to as the Precision Orbit Determination and Verification Team (PVT) was incorporated into the T/l' flight operations team. During the T/P mission the MOE production and POE verification has required only two people, with onc analyst as the lead and the other as a backup. The daily computations have been performed on an HP 9000/720 series workstation. A description of this process and an orbit quality assessment is given in Reference 2.

The amount of SLR data available on a daily basis has decreased throughout the past year duc to shrinking funding for the SLR network. This decrease in SLR data could lead to an erosion in orbit quality, especially eve] the holidays. Changes to the orbit determination strategy in operations has been avoided for the sake of consistency, which is desired by the science community using these orbits. However, the POE model changeover provided an opportunity to add a second data type to the MOE production, beyond simply updating the MOE models. GPS data is collected as quickly (if not quicker) than SLR data, which made it an excellent candidate for MOE production. Since launch, the reliability of the GPSDR software has increased considerably, and since early 1995 has operated nearly continuously. Figure 1 depicts the operational history of the GPSDR throughout the T/P mission.

Figure 1: T/P GPS Demonstration Receiver Tracking Status and GPS Constellation Anti-Spoofing Status (1993-Present)



The estimated stochastic acceleration parameters for the T/P spacecraft arc in 10 hour batches: a constant downtrack acceleration and once-per-orbit downtrack and crosstrack accelerations (cosine and sine components). The time boundaries of these empirical accelerations are moved when necessary to coincide with spacecraft attitude events (including yaw flips, transitions to/from yaw steering, and maneuvers). This heuristic practice has consistently yielded more accurate orbits. The constant downtrack acceleration estimates provide an indication of the secular decay (or growth) of the semimajor axis. The resulting change in mean motion shifts the ground track away from its planned track. These estimates are currently supplied to the project Navigation team as part of their ground-track monitoring. The constant downtrack acceleration estimates include an atmospheric drag component which is subsequently removed.

DATA DESCRIPTION

The SLR Global tracking network is a consortium of many groups of stations, including (i) the Crustal Dynamics CDSLR network, (ii) university-led sites (Haleakala and Ft. Davis), (iii) Fundamental Foreign sites (Bar Giyyora, Grasse, Herstmonceux, Matera, Orroral Valley, Shanghai, Simosato, Wettzell), (iv) additional key foreign sits (Graz, Helwan, Metsahovi, and Zimmerwald), (v) the Chinese SLR Network, and (vi) miscellaneous cooperating foreign sites. The SLR quick-look data is collected every weekday morning from the Crustal Dynamics Information System (CDDIS) electronically via FTP. Typically, SLR data for a given pass is available to the PVT within 4 days after-the-track. There are variations from this timing due to weekends, holidays, and the turnaround time of the station itself.

The GPS ground data used in this effort comes from a global network of 16 stations. This data is a subset of that collected and reduced at the Jet Propulsion Laboratory as part of an effort with the International GPS Geodynamics Service (IGS). The GPSDR data is also processed on-lab by members of the flight team. The GPSDR and GPS ground data are both available in well under 48 hours after-the-track.

The SLR and GPS data weights are summarized in Table 1. The SLR data weights used for MOE production are a function of station of origin, and are based on recommendations from the University of Texas, Austin. These weights range from 1.0 cm to 200 cm. CDSLR stations have well-monitored quality control on their data collection; stations from other organizations are not as standardized. in fact, SLR passes from some foreign stations are processed only on a volunteer basis. The GPS data weights (based on a 300 sec processing rate) are based on the experiences of the authors, as some of them have previous experience with T/P GPS data through the GPS Demonstration Experiment, The GPSDR phase and pseudorange data are deweighted as part of the strategy when the GPS constellation is in Anti-Spoofing mode. The optimal relative weighting between SLR and GPS data has not yet been determined. However, GPS/SLR orbits created with these weights are such an improvement over any SLR-only product that it was considered prudent to proceed with GPS/SLR production, even without this optimization.

Table 2: SLR and GPS Data Weights

SLR	GPS (Ground)		GPS (T/P)	
Two-way (cm)	Carrier Phase (cm)	Pseudorange (cm)	Carrier Phase (cm)	Pseudorange (cm)
1.0-200	1.0 -2.0	100	10, 80 (AS)	80, 240 (AS)